Jet Propulsion Laboratory
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The Origin, Age, and Stratigraphy of Mars' South Polar Cap

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LPSC

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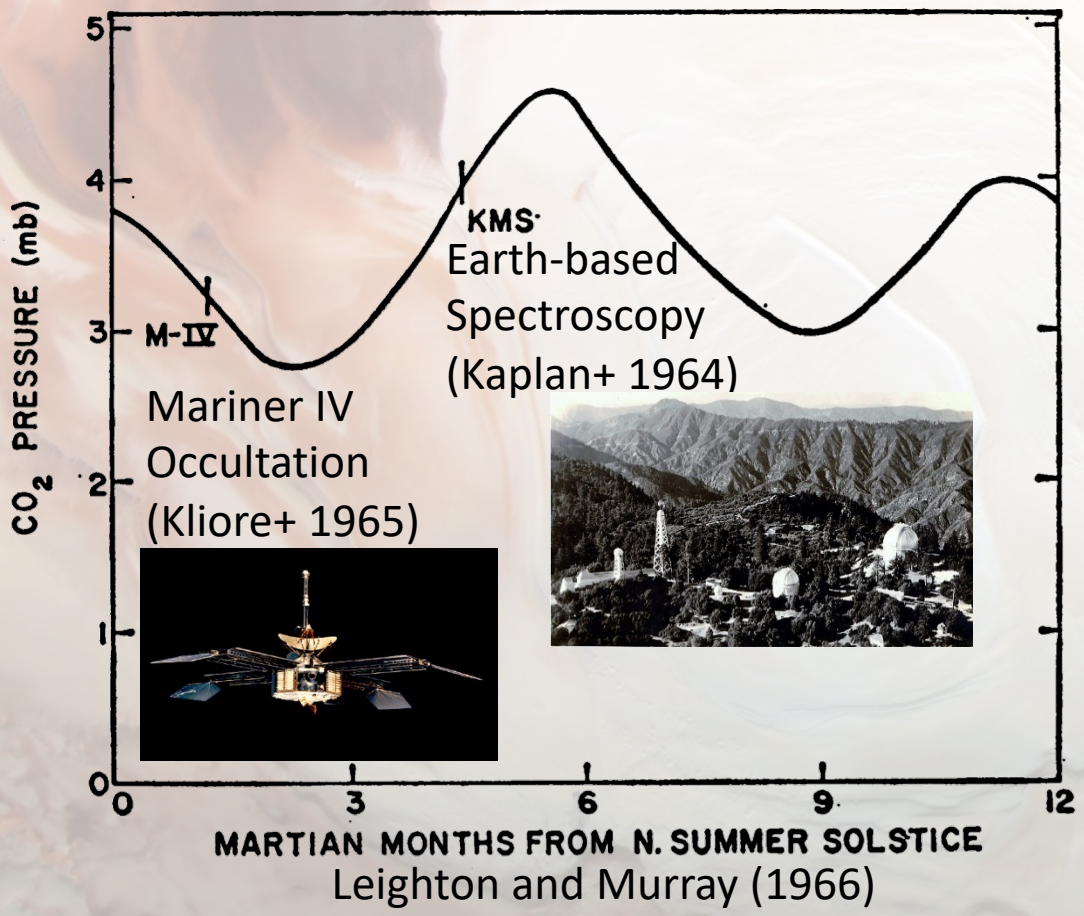
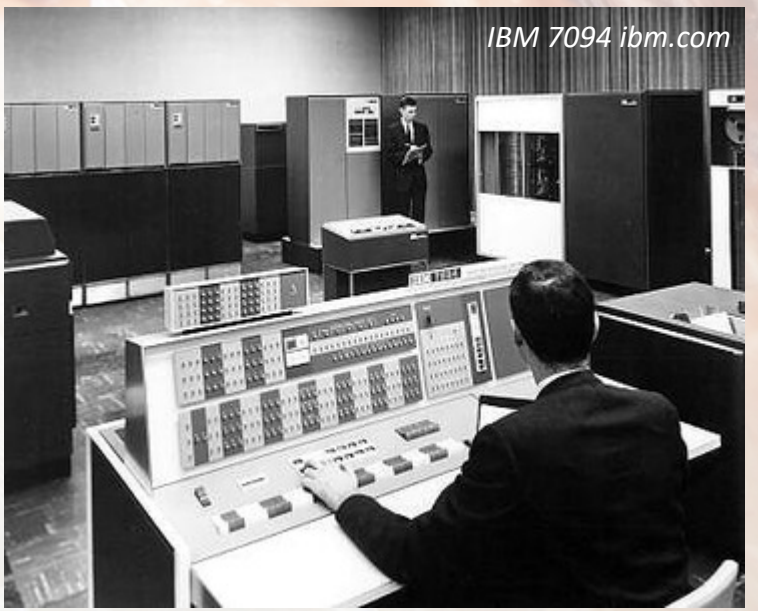
Background



Mariner IV Occultation (Kliore+ 1965)

Earth-based Spectroscopy (Kaplan+ 1964)

Leighton and Murray (1966)

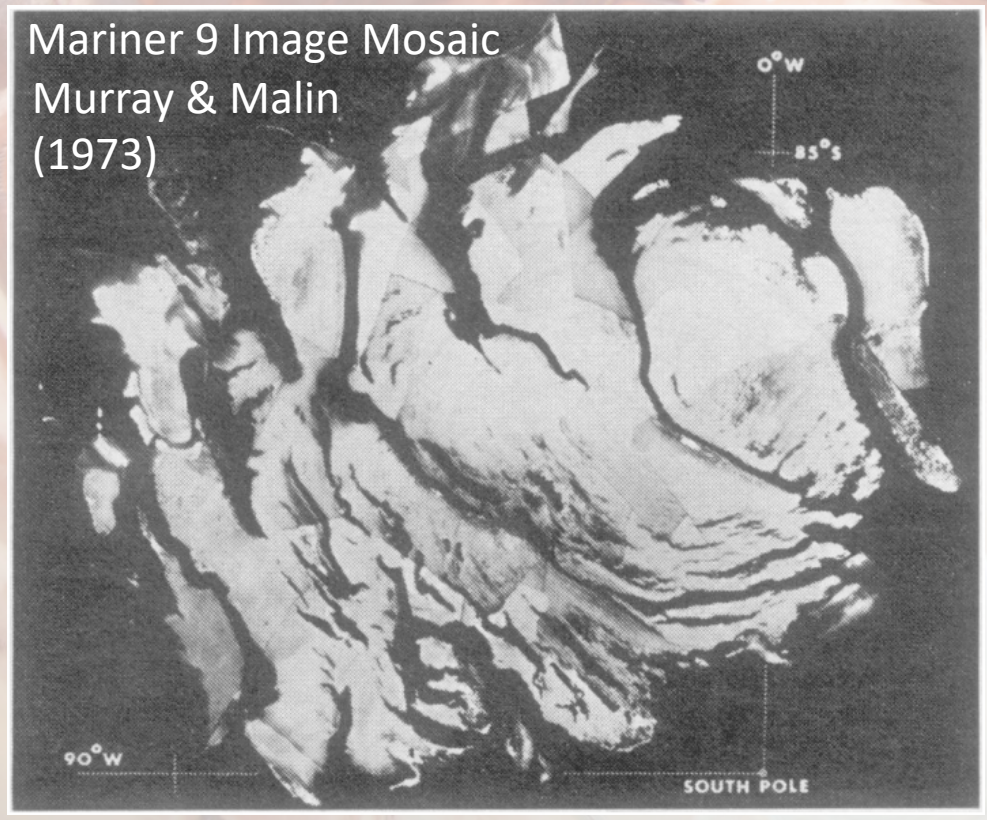


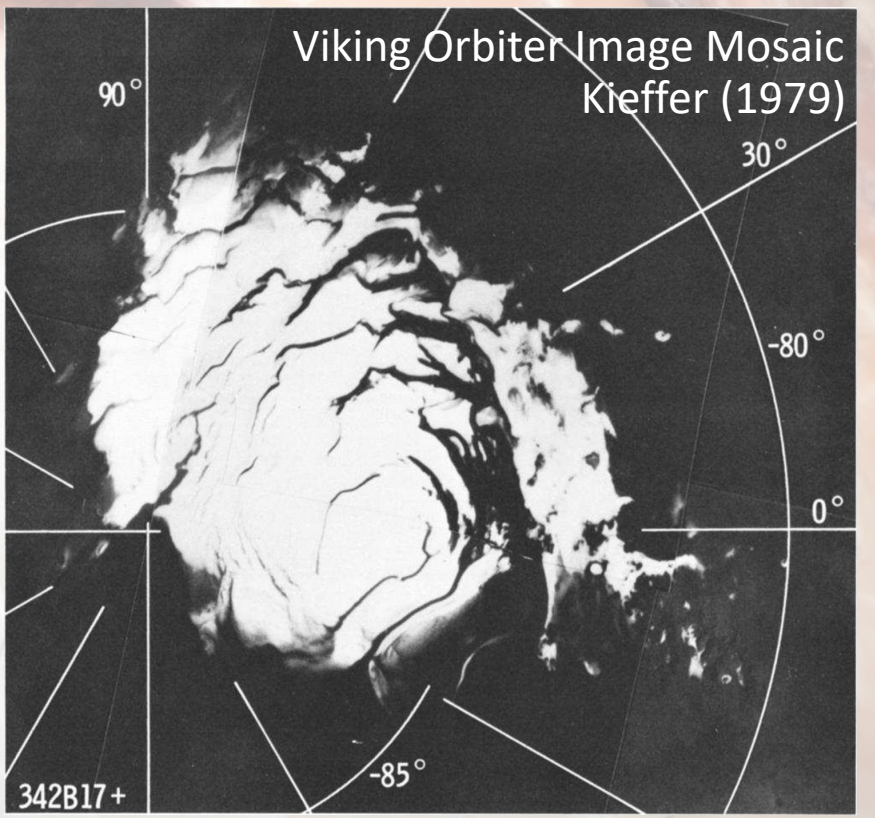
IBM 7094 ibm.com

Leighton

Murray

What is the RSPC?

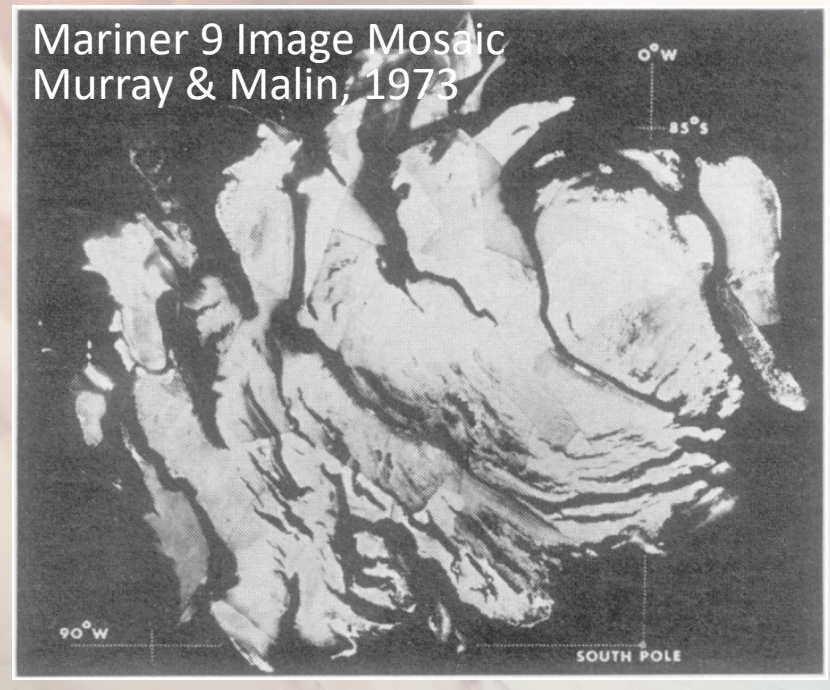




- "CO_2 ice could not survive in contact with low-albedo material."
- "Therefore, a residual water-ice cap is much more stable than a solid CO_2 one on Mars in the summertime."

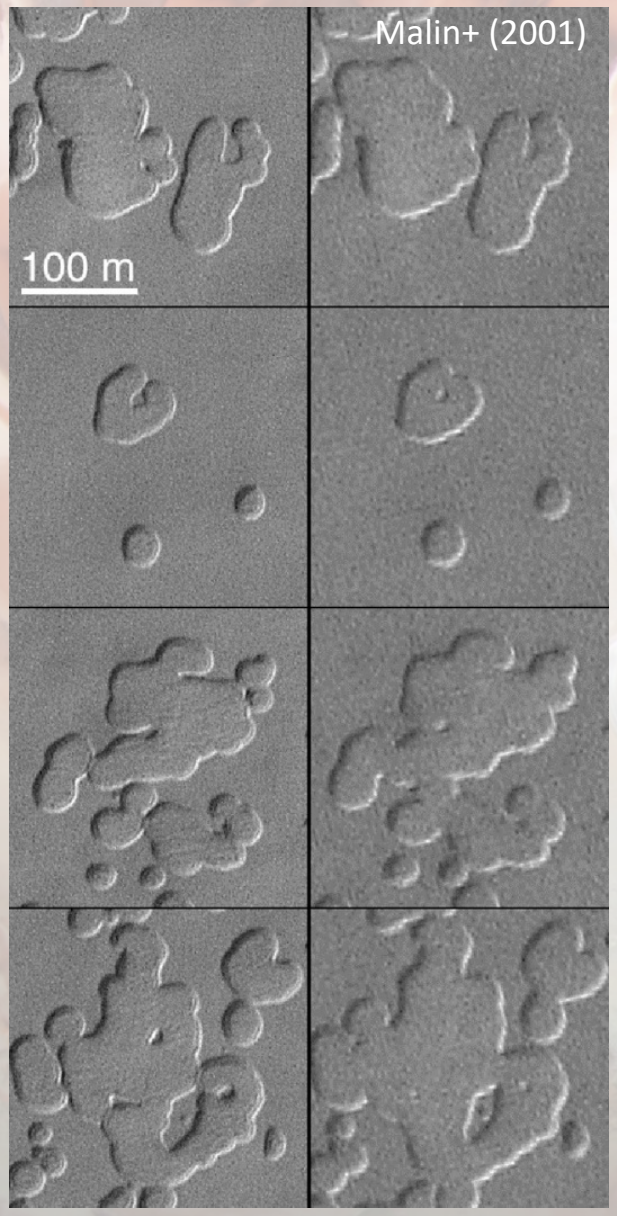
- "Throughout the summer, the polar frost remained at the temperature of solid CO_2."
- "Thus Mars appears to have a residual polar cap of CO_2 in the south and one of H_2O in the north."

OK, it's CO_2, but why at the South Pole?

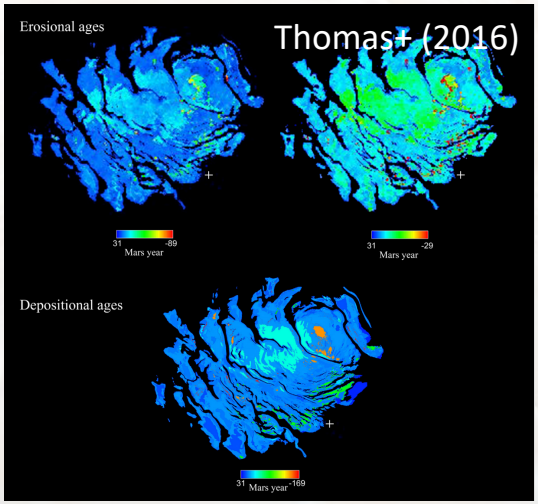


- "[From occultation] it can be seen that the southern residual cap must be higher than the northern one by at least 2 km."
- "Any solid CO_2 in the south would be in contact with atmospheric CO_2 at a pressure lower by about 2 mbar than in the north."
- "There is no reason to suppose a permanent CO_2 southern cap would be at a systematically lower temperature than the northern one."
- "Hence, solid CO_2 deposits in the south would be out of equilibrium and would gradually be transferred to the north…in well under 1000 years."
- "Excess solid carbon dioxide is probably present [buried] in the north residual cap."

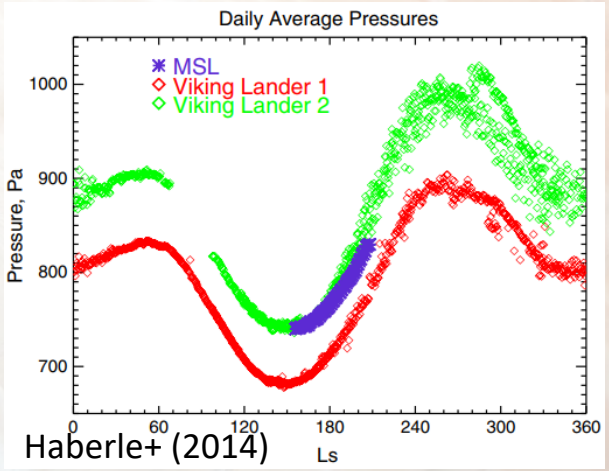
Is the RSPC disappearing?



- "The erosion … and other observations suggest that the present martian environment is neither stable nor typical of the past." –Malin+ (2001)

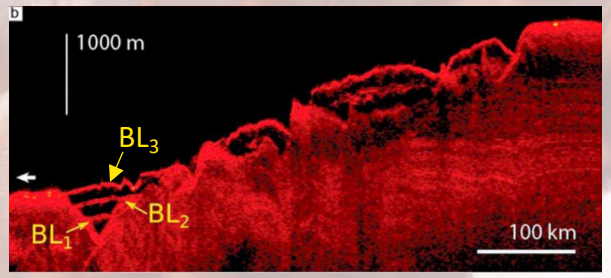


RSPC mass balance in Mars years 9–31
~ -0.039% to +0.026% mean atmospheric CO_2 mass per martian year.

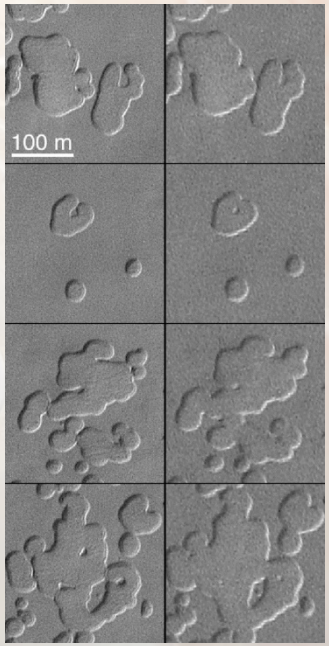


Viking vs. Curiosity pressure curves: no evidence yet for the 1–20 Pa increase expected from the possible loss of CO_2 from RSPC.

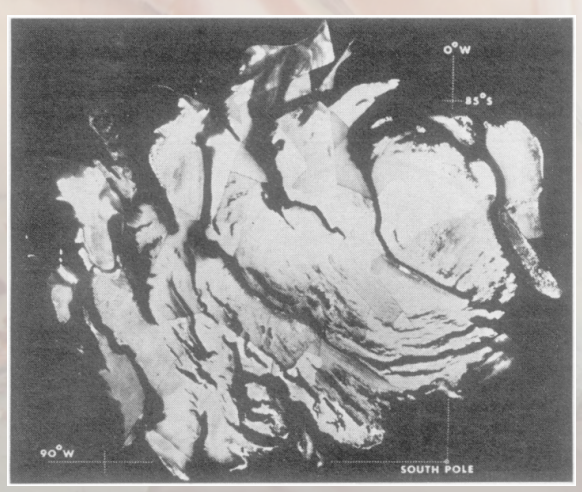
3 Outstanding Questions



1. How was the massive CO_2 deposit emplaced with its observed stratigraphy?

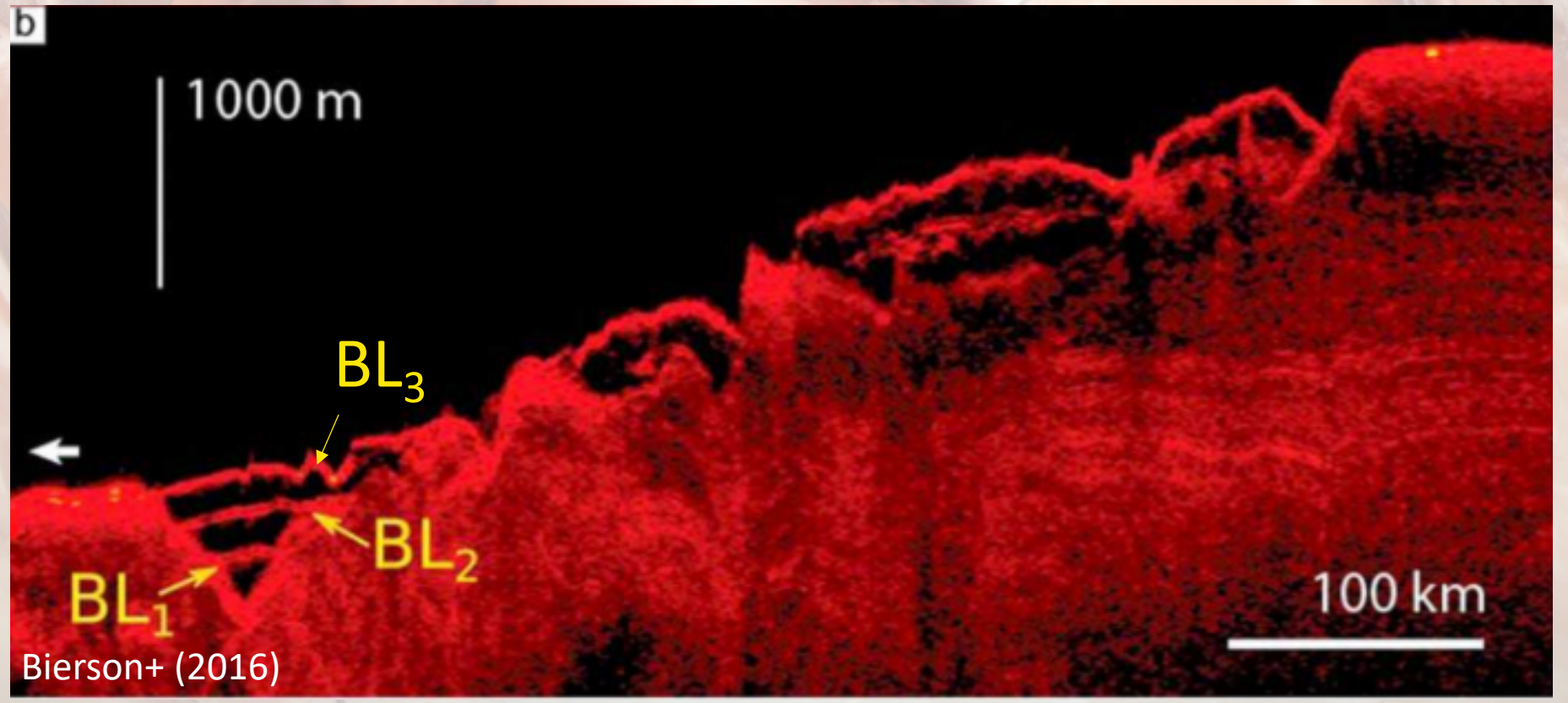


2. Why does the RSPC exist?



3. Why is permanent CO_2 at the south pole (not the north)?

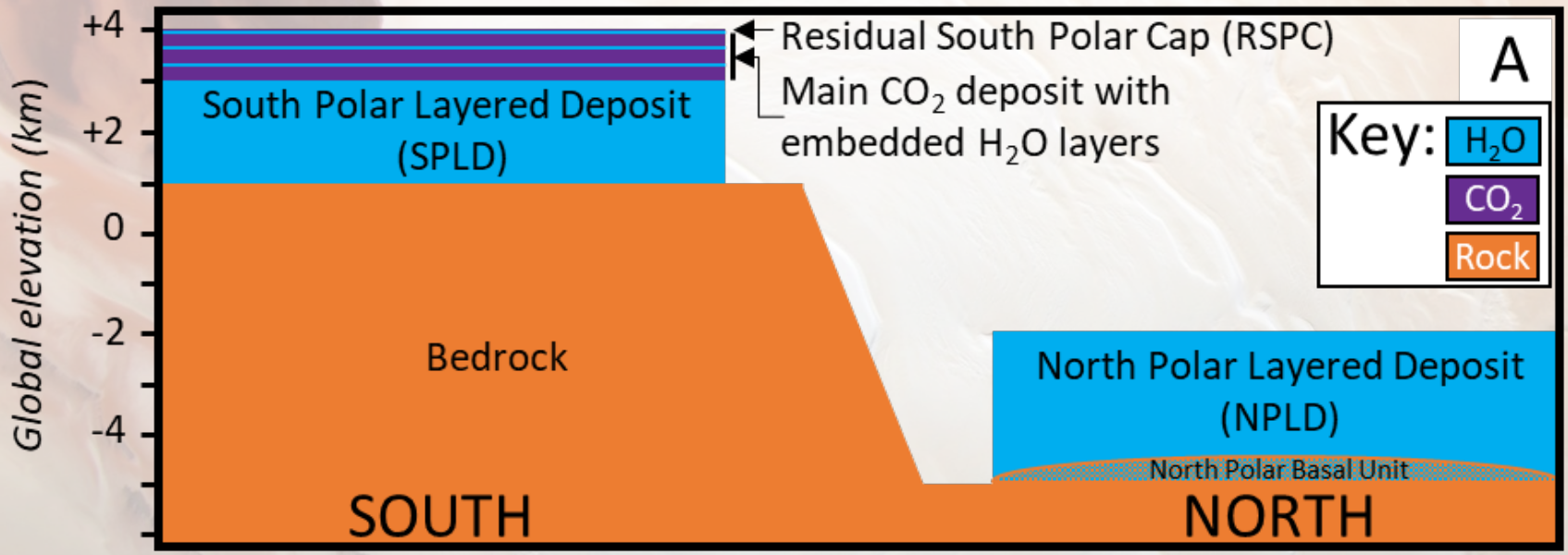
The massive CO_2 deposit



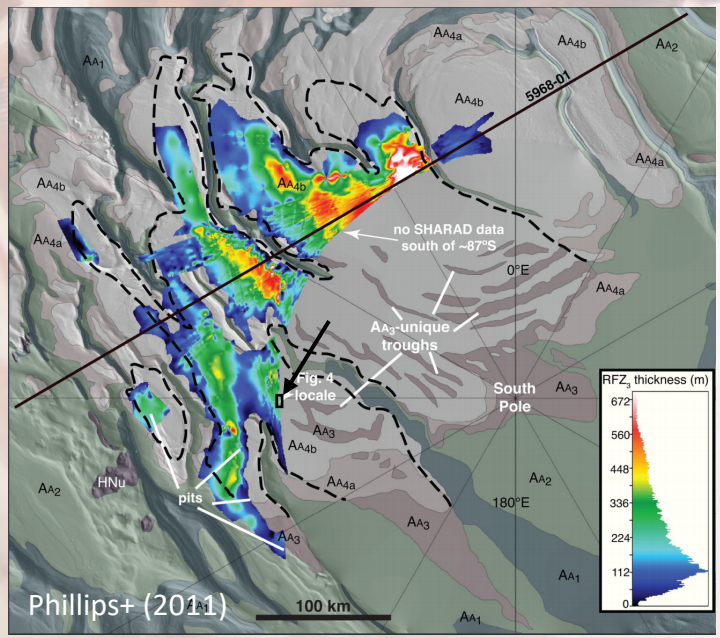
"We find three distinct CO_2 subunits, each capped by a bounding layer (BL)." –Bierson et al. (2016)

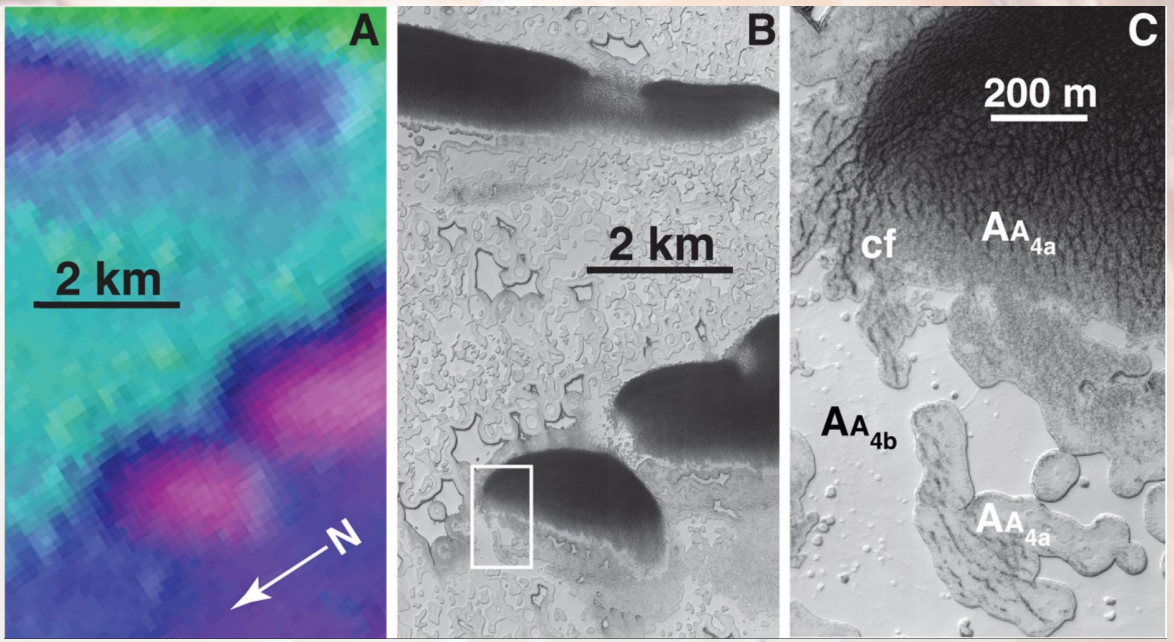
- "CO_2 ice is deposited over much of the poles during low obliquity periods."
- "A remnant is sequestered below a water ice deposit (BL subunits), removing it from contact with the atmosphere."

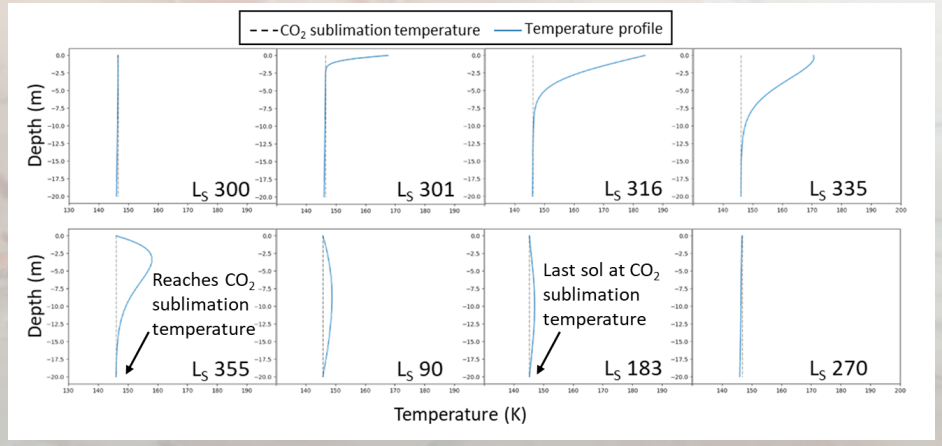
Schematic Polar Stratigraphy



Does the H_2O seal the deposit?



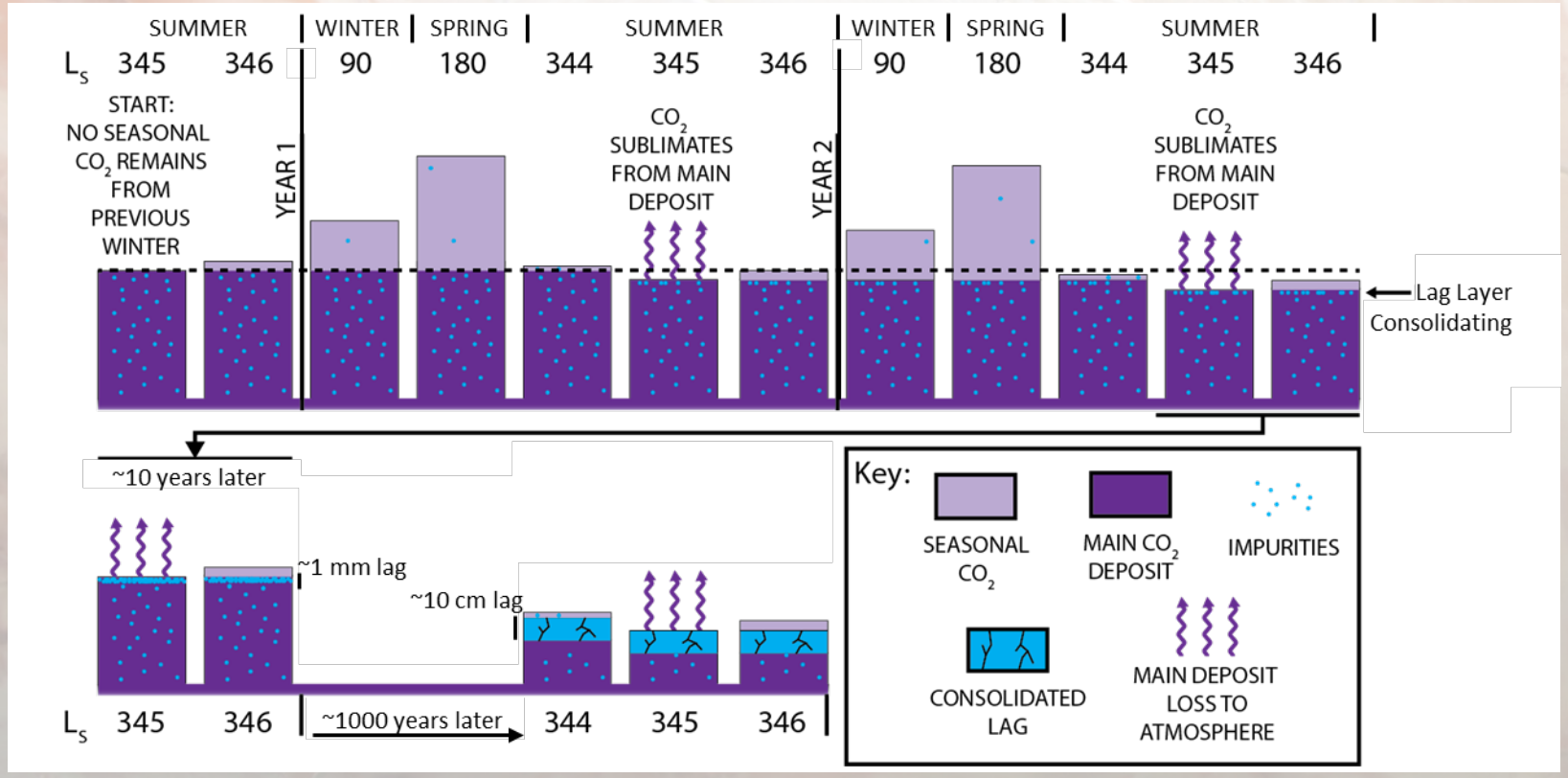




- "All of these smaller troughs, depressions, and pits appear to result from erosion and removal of unit A_{A3} [the massive CO_2 deposit], with a strong component of sublimation and collapse."
- "The fracturing, not found in other SPLD units, may be a response to continuing unit A_{A3} sublimation after the pits had first formed."

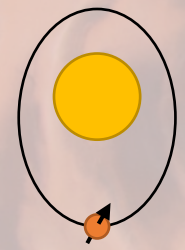
Is the RSPC an extraordinary accident?

- If the massive CO_2 deposit is sequestered from the atmosphere, the same problem of "extraordinary accident" exists.
- *"A scum layer of dark (low albedo) material may be buried beneath a topmost layer of frost, but as soon as this topmost layer is removed, the dark dust [or H_2O ice] will heat up and any CO_2 beneath it will escape." –Murray and Malin (1973)*
- But what happens next?

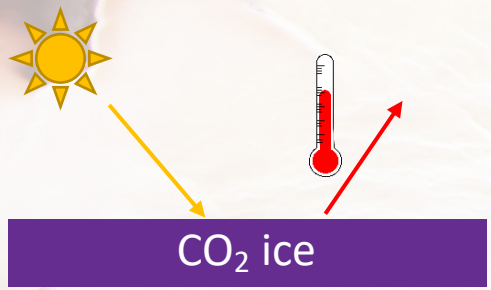


Mars' Pressure History

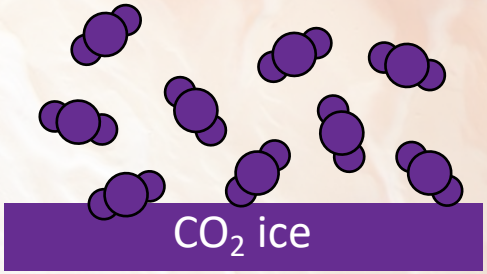
Use a look-up table:



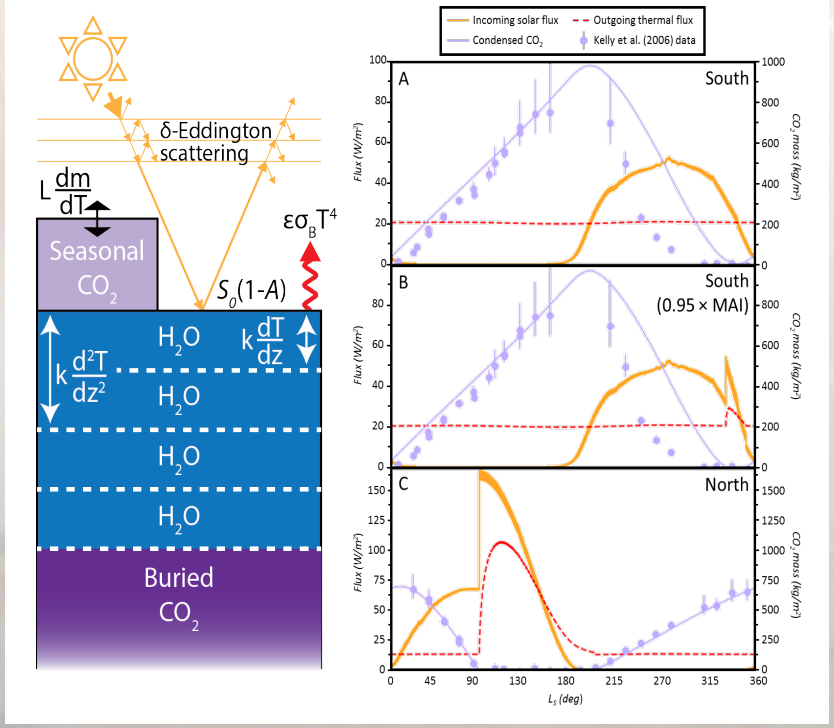
Any orbit



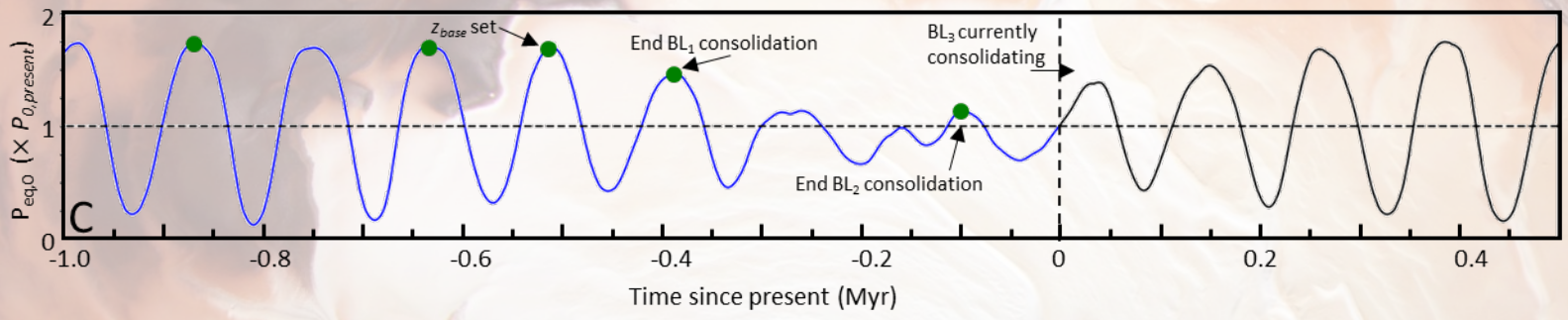
Equilibrium Frost Temperature

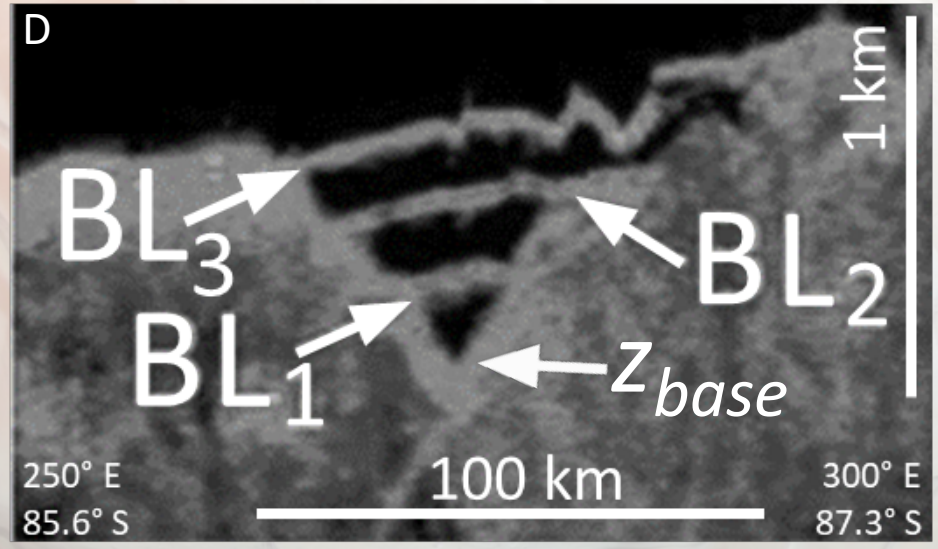


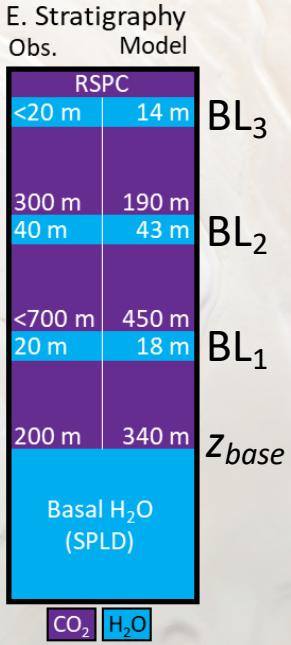
Equilibrium Pressure



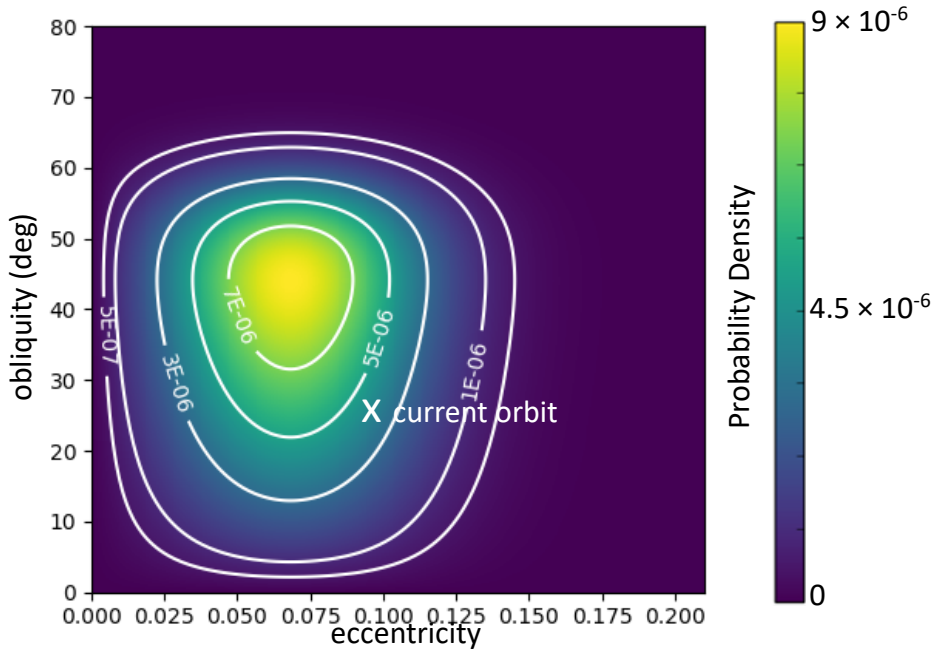
Mars' Pressure History and Stratigraphy

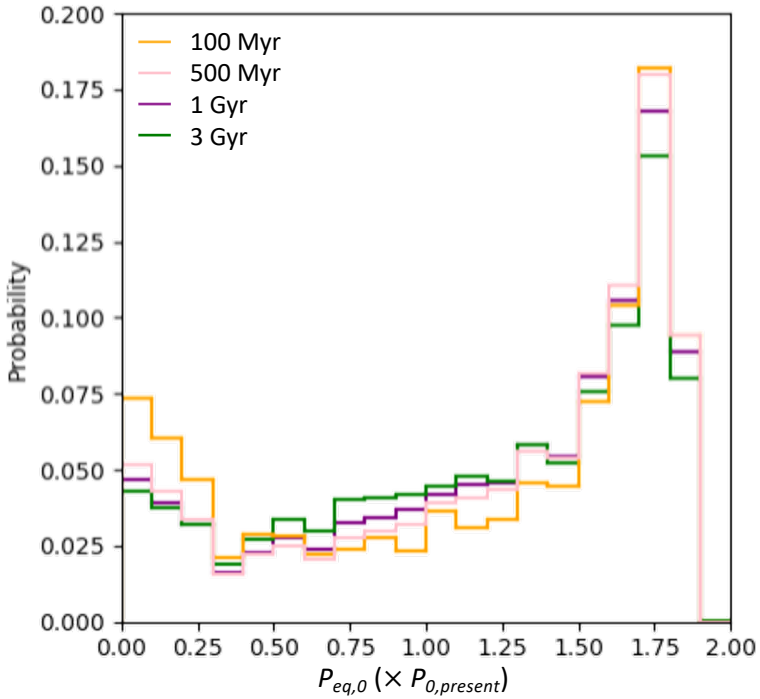






Long-term pressure history of Mars





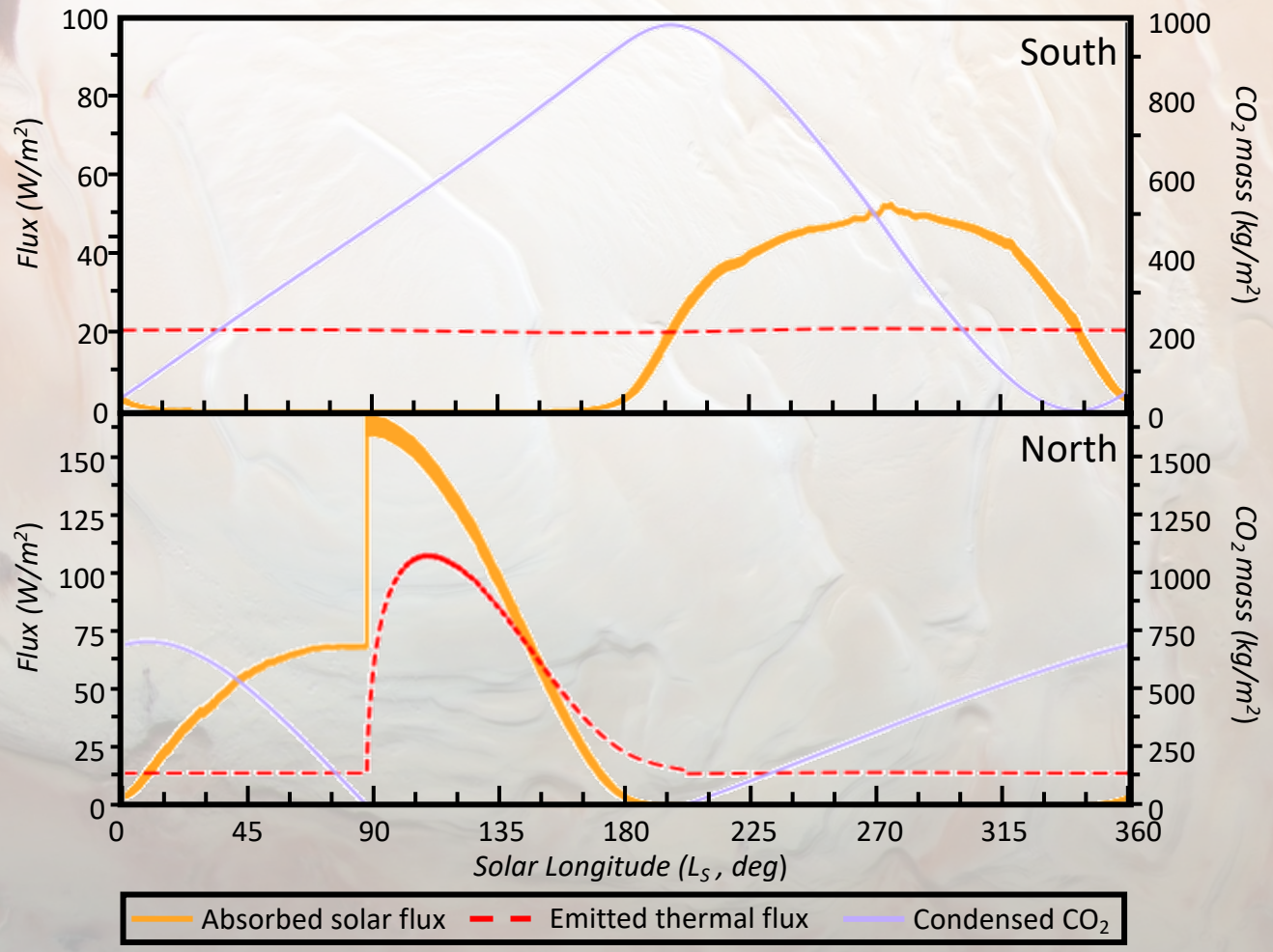
- Median Amazonian pressure: 1.32 × present
- Interquartile range: 0.77 to 1.67 × present

Why is the permanent CO_2 in the south?

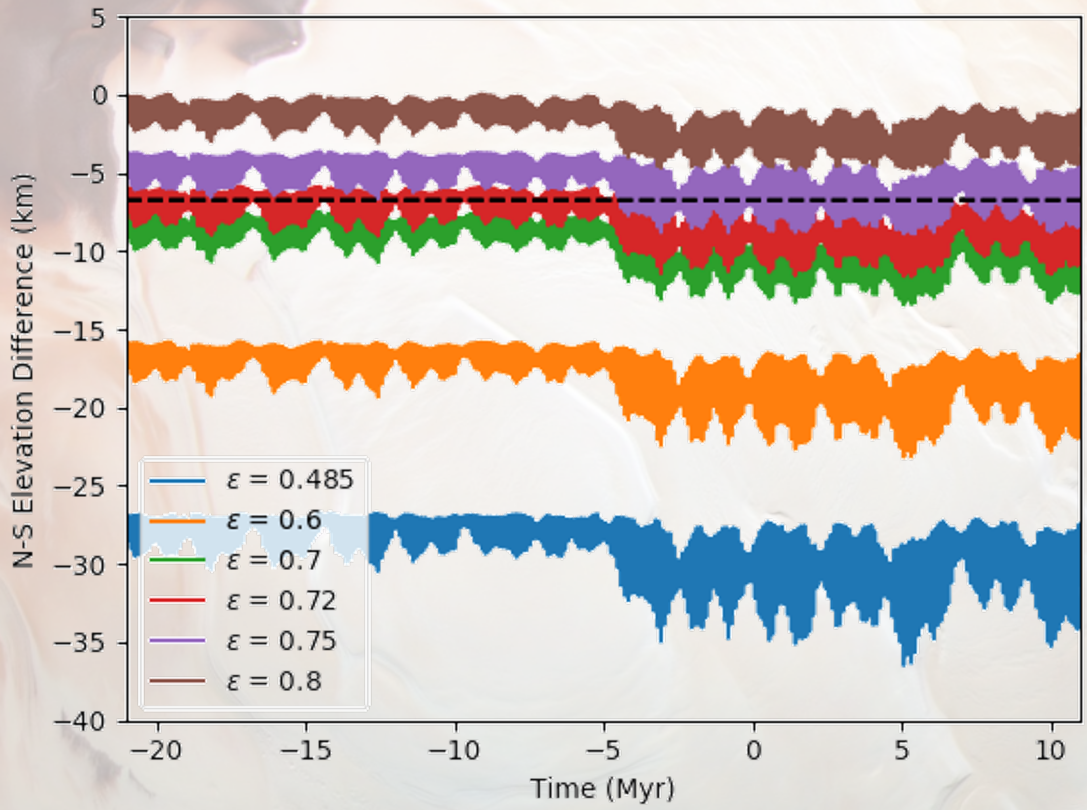
"There is no reason to suppose a permanent CO_2 southern cap would be at a systematically lower temperature than the northern one."
– Murray and Malin (1973)

$\bar{A}_{CO_2} \approx 0.7$
$\epsilon_{CO_2} \approx 0.8$

$\bar{A}_{CO_2} \approx 0.63$
$\epsilon_{CO_2} \approx 0.49$

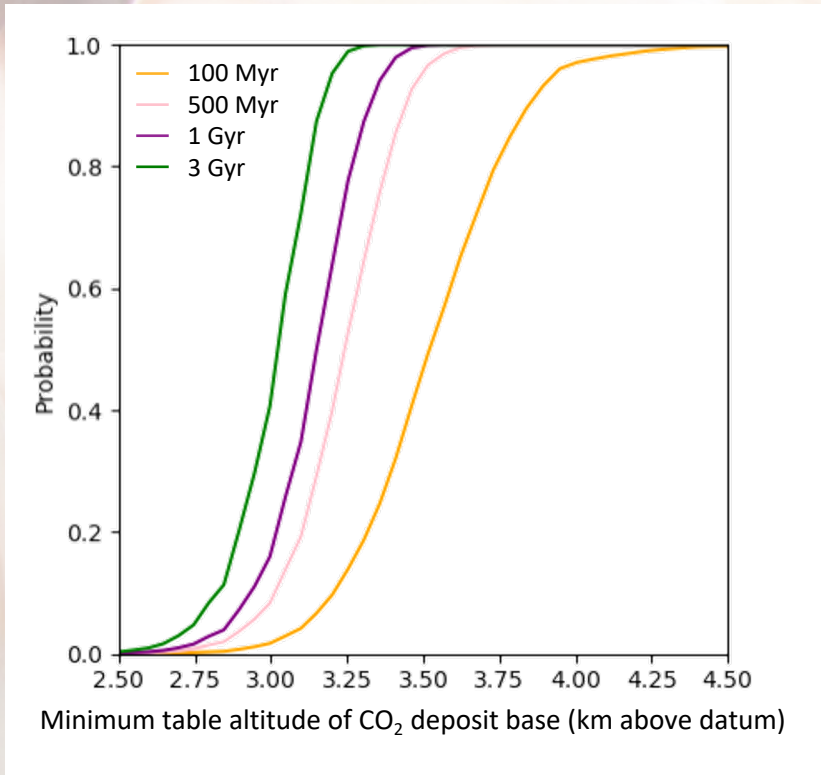


Will perennial northern CO_2 ever exist?



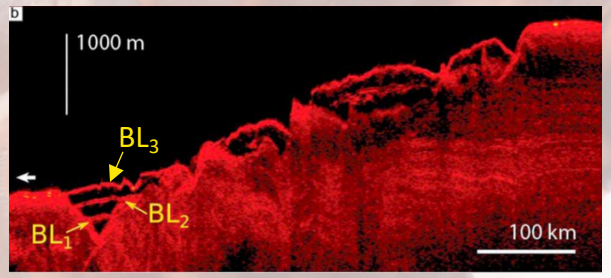
Would require significant changes to $\bar{A}_{CO_2}$ and/or ϵ_{CO_2}

CO_2 protects the SPLD at high obliquity



- CO_2 protects the SPLD from ablating.
- CO_2 does not protect the NPLD.

Conclusions

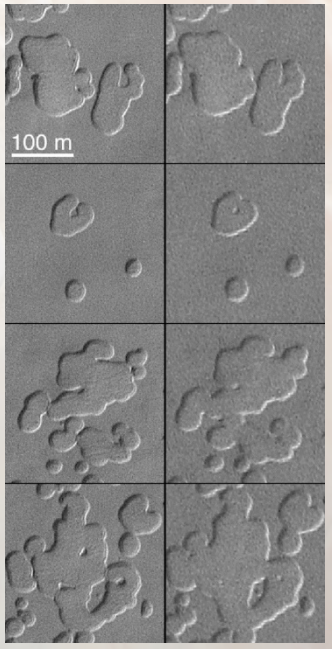


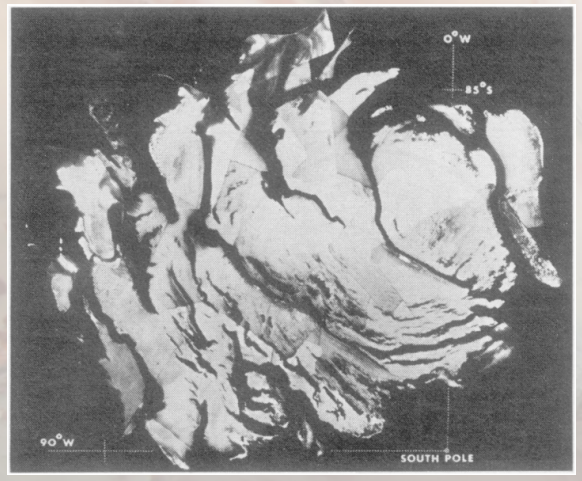
1. How was the massive CO_2 deposit emplaced with its observed stratigraphy?

Equilibrated co-evolution with the atmosphere, driven by orbital forcing. H_2O impurities accumulate into lag deposits.

2. Why does the RSPC exist?

Negative feedback between surface CO_2 ablation, dark lag formation, and basal CO_2 sublimation.





3. Why is permanent CO_2 at the south pole (not the north)?

The albedo/emissivity of the southern CO2 is higher, overwhelming the lower elevation of the northern cap.

Questions?